Correlation between morphology, behaviour and habitat - bivalve burrowing in simulation and robotics

Germann, Daniel ; Schatz, Wolfgang ; Hadorn, Maik ; Fischer, Andreas ; Eggenberger Hotz, Peter

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3. Palaeontology (Open Session)

Damien Becker

Swiss Palaeontological Society (SPS)
Kommission des Schweizerischen Paläontologischen Abhandlungen (KSPA)

REFERENCES
Basse, E., & Choubert, G. 1959: Les faunes d'ammonites du "Cénomano-Turonien" de la partie orientale du domaine atlasique marocain et de ses annexes sahariennes, C. R. 20th International Geological Congress. In L. B. Kellum (ed.) El Sistema Cretacico, 2, 59-81.
Dubar, G. 1949: Carte géologique provisoire du Haut-Atlas de Midelt, notice explicative. In: Notes et Mémoires du Service géologique du Maroc, 1–56.
Lavocat, R., 1948. Découverte de Crétacé à vertébrés dans le soubassement de l'Hammada du Guir (Sud marocain), C. R. Académie des Sciences, Paris 226, 1291–1292.
Lavocat R., 1949. Les gisements de vertébrés crétacés du Sud marocain, C. R. sommaires de la Société Géologique de France, 19, 125–126.

3.6

Correlation between morphology, behaviour and habitat – bivalve burrowing in simulation and robotics

Germann Daniel*, Schatz Wolfgang**, Hadorn Maik*, Fischer Andreas* & Eggenberger Hotz Peter*

*University of Zurich, Department of Informatics, Artificial Intelligence Laboratory, Andreasstrasse 15, CH-8050 Zurich (germann@ifi.uzh.ch)
**University of Lucerne, Pfistergasse 20, CH-6003 Lucerne

Bivalves show a large diversity of shell shapes and sculptures during their long history of evolutionary adaptations to different modes of life. The comparatively dense fossil record of bivalves, the well-defined morphological space and the quite complete picture of bivalvian phylogeny offer basis for an analysis of general evolutionary processes. However, while the fossil record conveys information about the shape and the habitat of bivalves, the interpretation of the functional morphology, locomotion and changes in shell shape is generally vague, as fossils represent only discrete states in the morphological space and suffer from the preservational bias. Thus, the purpose of this project is to extend the knowledge about the evolution of bivalves and their adaptations to burrowing using both a computer simulation and a burrowing robot. The simulation will cover the dynamics of burrowing as well as the evolution in morphology and behaviour, reconstructing a trajectory in the morphological space and analysing the processes inducing these state-shifts.

There already exist mathematical models of sea shells (e.g. Raup & Michelson 1965), models of granular media (e.g. van Wachem & Almstedt 2003), burrowing robots and simulations of artificial evolution, but they have never been combined. Our simulation consists of (i) models of recent, fossil and artificial bivalve morphospecies, (ii) a model of a granular medium including the physical interactions with the shell, (iii) an implementation of the burrowing sequence (cf. Trueman 1966) and (iv) an artificial evolutionary system. The artificial evolution may change parameters controlling the behaviour or the morphology of the bivalves. Using a computer simulation allows an efficient and systematic analysis of the burrowing efficiency by changing just a single parameter at a time.

The virtual shell models are converted into physical objects using a 3D-printer (Fig. 1). As a starting point for the physical experiments, finally leading to a self-sufficient burrowing robot, we will attach the shell to two rods simulating the rocking locomotion of the bivalve during the burrowing process (cf. Stanley 1975). In further steps, the opening and closing of the valves and finally an artificial foot probing into the sediment will be added to complete the robot. The data provided by the robot is used to calibrate the simulation and to assess the coherence of the model and the physical reality. After testing the biological significance of the simulation, we will explore the functional correlations between the shell shapes and sculptures, the burrowing behaviour and the sediment type.

As shown in earlier examples (Hadorn et al. 2004), a close collaboration between palaeontology and evolutionary computation/robotics can return profit for both scientific fields. A possible application of this research may be a tool for palaeontologists to link shell forms and the mode of life of fossil bivalves in a more sophisticated way. The simulation can be used to perform experiments with evolution, to identify functional constraints, to find explanations for aberrant and extinct shell forms and even to create and test shell forms that have never existed. By investigating the functionality not only of recent but also of fossil shells, the field of bionics could be remarkably extended. In industry, the robot might serve as a prototype for autonomous burrowing robots or removable and fixed anchorage of man-made structures in soft sediments.

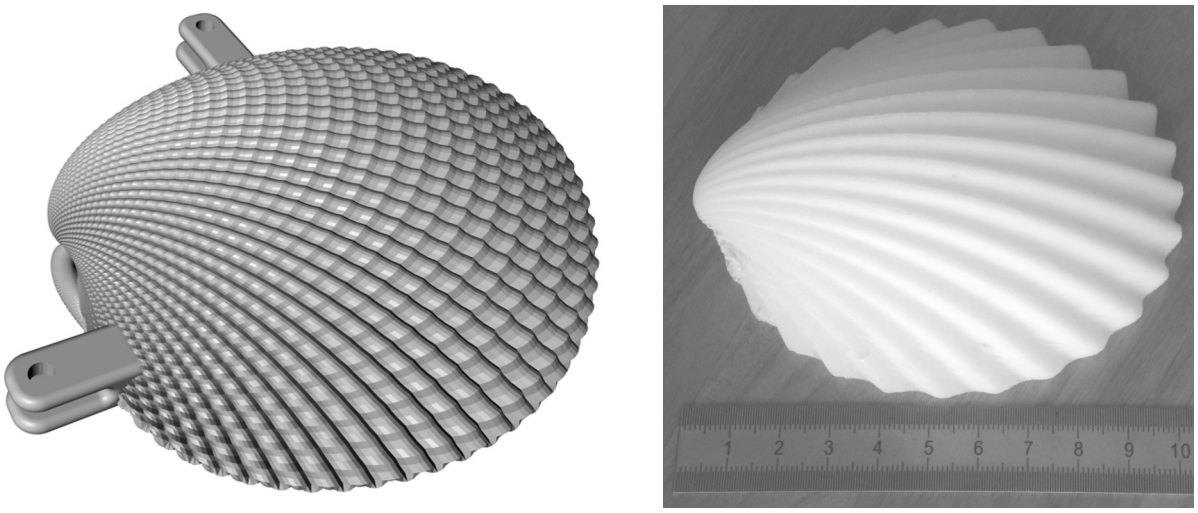

Figure 1. Left: An artificial shell generated by the simulation software with added sockets for the rods. Right: Photo of a valve printed by the 3D-printer (scale in centimetres).

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REFERENCES

Hadorn, M., Schatz, W. & Eggenberger Hotz, P. 2004: Were Adam and Eve Ediacarans? – A possible sexual dimorphism in Dickinsonia costata, Abstracts of the 2nd Swiss Geoscience Meeting.

Raup, D. & Michelson, A. 1965: Theoretical morphology of the coiled shell, Science, 147, 1294-1295.

Stanley, S. 1975: Why clams have the shape they have; an experimental analysis of burrowing, Paleobiology, 1, 48-58.

Trueman, E. 1966: Bivalve mollusks: Fluid dynamics of burrowing, Science, 152, 523-525.

van Wachem, B. & Almstedt A. 2003: Methods for multiphase computational fluid dynamics, Chemical Engineering Journal, 96, 81-98.

3.7

Smithian-Spathian boundary: the biggest crisis in Triassic conodont history

Goudemand Nicolas*, Orchard Mike**, Bucher Hugo*,***, Brayard Arnaud****, Brühwiler Thomas*, Galfetti Thomas*, Hermann Elke*, Hochuli Peter A.*,*** & Ware David*.

**Paläontologisches Institut und Museum der Universität Zürich, Karl Schmid-Str.4, CH-8006 Zürich (goudemand@pim.uzh.ch).*
***Geological Survey of Canada, Vancouver, Canada.*
****Department of Earth Sciences, ETH Zürich, Switzerland.*
*****LMTG, UMR 5563 CNRS, Université Toulouse IRD, France.*

Ongoing work in California, S-China, Tibet, Pakistan and Oman has led to a refined biochronologic subdivision of the late Early Triassic and allows reconstructing a high resolution diversity time series, partly constrained by new U-Pb ages from S-China (Galfetti et al. 2007a).

Conodonts crossed the PTB without major changes (Orchard 2007). In the Early Triassic the first major conodont faunal turnover occurred during the late Griesbachian - early Dienerian, with the disappearance of Anchignathodontids (*Hindeodus-Isarcicella* group), which were replaced by the emergent *Neospathodus* and *Borinella*? species.

In the earliest Smithian, conodonts experienced a dramatic radiation, which ended in a major extinction during the late Smithian. This extinction was the most severe of the entire Triassic in terms of generic diversity and multi-element apparatuses. In the early Spathian conodonts radiated again explosively and gradually declined during late Spathian times.

These global diversity patterns coincide with large perturbations of the global carbon cycle (Brühwiler et al. 2007; Galfetti et al. 2007b, Payne et al. 2004). As indicated by changes in the latitudinal gradient of generic richness of ammonoids, the boreal palynological record, and a prominent positive $\delta^{13}C$-isotope shift, the late Smithian - early Spathian boundary interval is marked by a severe climatic change.